

# The Relativistic Heavy Ion Collider

## BNL/PHENIX Group

David Morrison

DOE NP RHIC Science & Technology Review  
23 – 25 August 2016



# Group composition and responsibilities

- Primary responsibility is operation of PHENIX experiment, hosting of activities – e.g, visitor support, computing, meetings, publication support – and research activity to optimize scientific output of the collaboration.
- Model of strong research involvement with PHENIX has been very successful – areas of particular expertise (e.g., neutral pions, photons, global observables, fluctuations), and ability to attract capable scientists
- Group leader (Morrison), two deputies (Steinberg, Woody) – work in conjunction with leaders of specific activities to coordinate and direct effort of group
- Current PHENIX activities include technical crew working on PHENIX R&R
- Activities directed toward anticipated sPHENIX project
  - detector prototypes and test beam activities
  - sPHENIX project management
- ATLAS HI physics analysis & ZDC project lead
- R&D (LDRD, PD, PECASE, TSAs (tech. service agreements), EIC R&D)

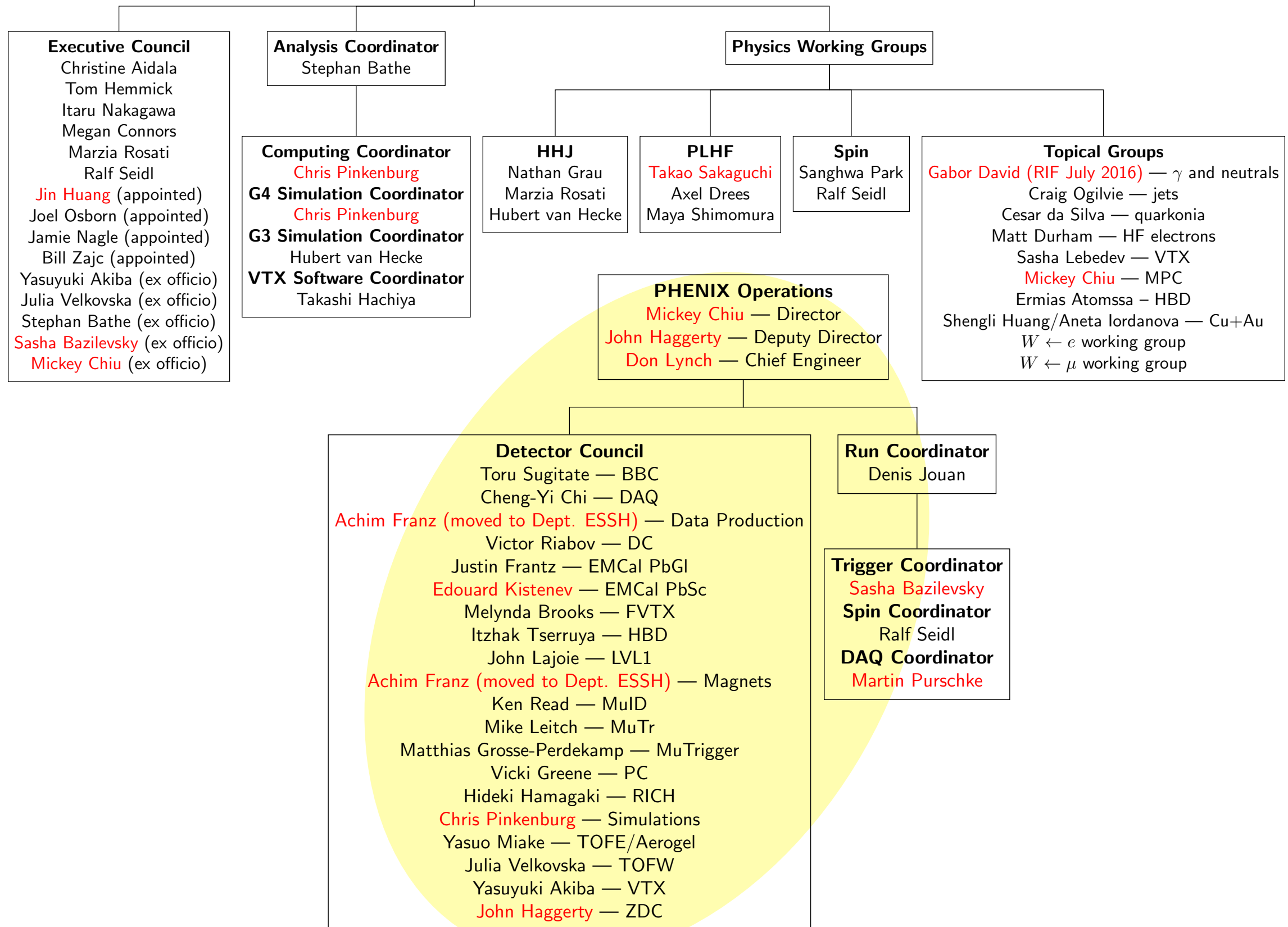
## PHENIX

D. Morrison, GL  
P. Steinberg, DL  
C. Woody, DL  
M. Faulkner, GA  
B. Azmoun  
J. Biggs  
S. Boose  
M. Chiu  
G. David  
E. Desmond  
A. Franz  
P. Giannotti  
J. Haggerty  
J. Huang  
E. Kistenev  
J. La Bounte  
W. Lenz  
M. Lenz  
D. Lynch  
E. Mannel  
J. Mills  
R. Nouicer  
E. O'Brien  
C. Pinkenburg  
R. Pisani  
S. Polizzo  
C. Pontieri  
M. Purschke  
T. Sakaguchi  
I. Sourikova  
S. Stoll  
Y. Suenaga  
A. Sukhanov  
M. Tannenbaum  
F. Toldo  
J. Tradeski

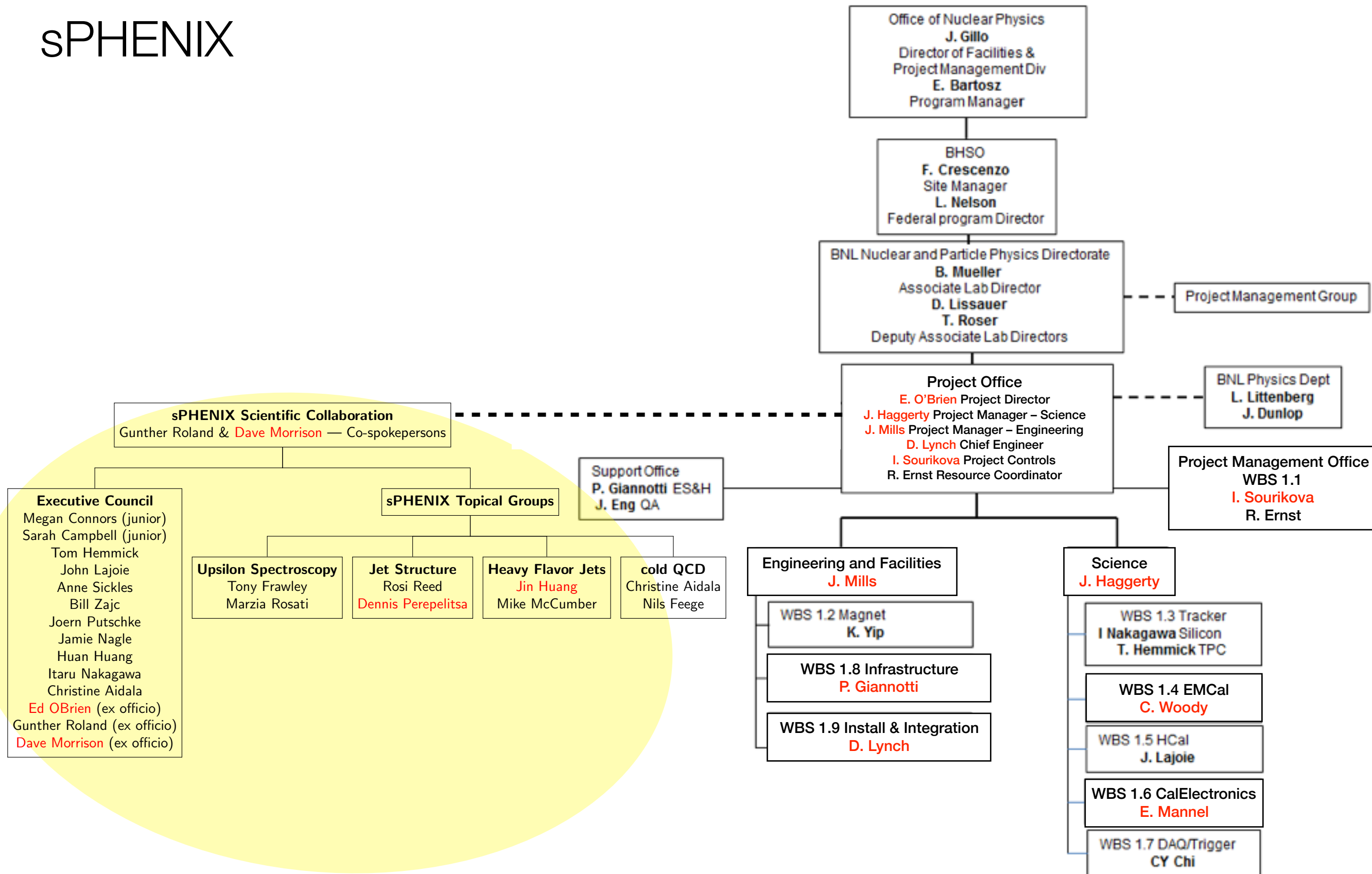
# PHENIX

**PHENIX Scientific Collaboration** Yasuyuki Akiba — Spokesperson  
 Julia Velkovska — Deputy Spokesperson  
 Stephan Bathe — Deputy Spokesperson  
 Sasha Bazilevsky — Deputy Spokesperson

Jamie Nagle, Dave Morrison co-spokespersons through 2015  
 Publication support: Brant Johnson (RIF July 2016; contract for 20% FTE)  
 Web support: Hyon-Joo Kehayias (voluntary RIF December 2015)



# sPHENIX



# PHENIX Operations

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BNL/PHENIX group has provided key support to maintain and operate detector, and to build and improve equipment

red = DC Member/Subsystem Leader

DAQ – **Martin Purschke**, Ed Desmond, John Haggerty, Mickey Chiu

ONLCAL/ONLMON/RCF Liaison – **Chris Pinkenburg**

ZDC – **John Haggerty**

MPC – **Mickey Chiu**

MPC-EX – Edward Kistenev, Andrey Sukhanov, Steve Boose

EMC – **Edouard Kistenev**, Sean Stoll, Jeff Mitchell

RICH – Takao Sakaguchi

VTXS/VTXP – **Rachid Nouicer**, Eric Mannel, Mike Lenz, Rob Pisani

FVTX – Jin Huang

HV – **Martin Purschke**, Sal Polizzo

LV – **Steve Boose**, Sal Polizzo, John Haggerty

Safety Systems – **Paul Giannotti**, Frank Toldo

Gas Systems – **Carter Biggs**, Rob Pisani, John Tradeski

Slow Controls – **Steve Boose**, John Haggerty, Frank Toldo

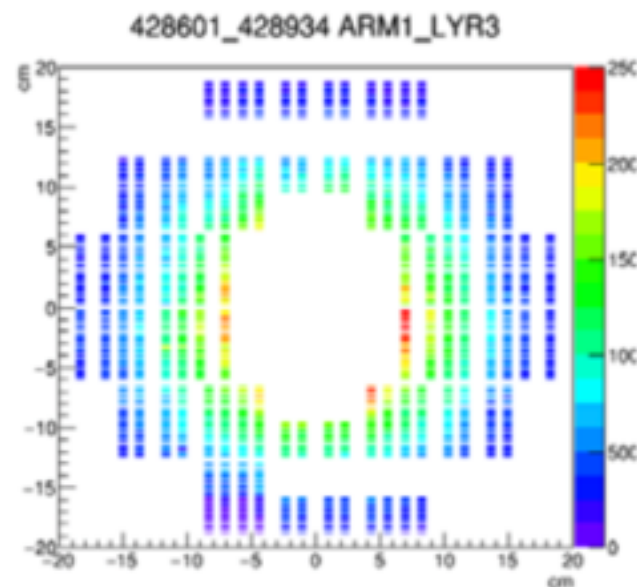
Magnets – **Achim Franz**

Infrastructure Support – **Carter Biggs**, Don Lynch, Jimmy Labounty, John Tradeski

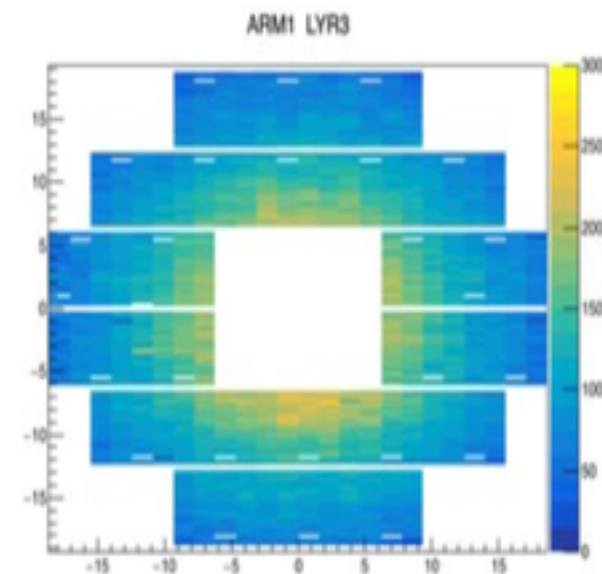
# PHENIX Operations - maintain/improve detectors

1. MPC-EX W-Si preshower for forward direct  $\gamma$ 
  - FEM+Carrier Boards: A. Sukhanov (moved to C-AD)
  - HV/LV Distribution Boards: S. Boose
  - DAQ Integration: E. Desmond, M. Purschke
  - Mechanical Design: D. Lynch, R. Ruggiero
  - Installation: J. Labounty, C. Biggs, F. Toldo
  - Firmware improvements Run15 to Run16  $\Rightarrow$  95% live

Run15



Run16



2. VTX/FVTX cooling system improvements for Run15
  - Run14 static discharge and condensation issues
  - No issues in cooling system for Run15/16
3. Repair of MPC and VTX damaged by beam dumps in Run15 p+Au
  - Protection diodes added to MPC
  - VTX-S ladders reconfigured to maximize live area

# Scientific productivity since 2014 S&T review

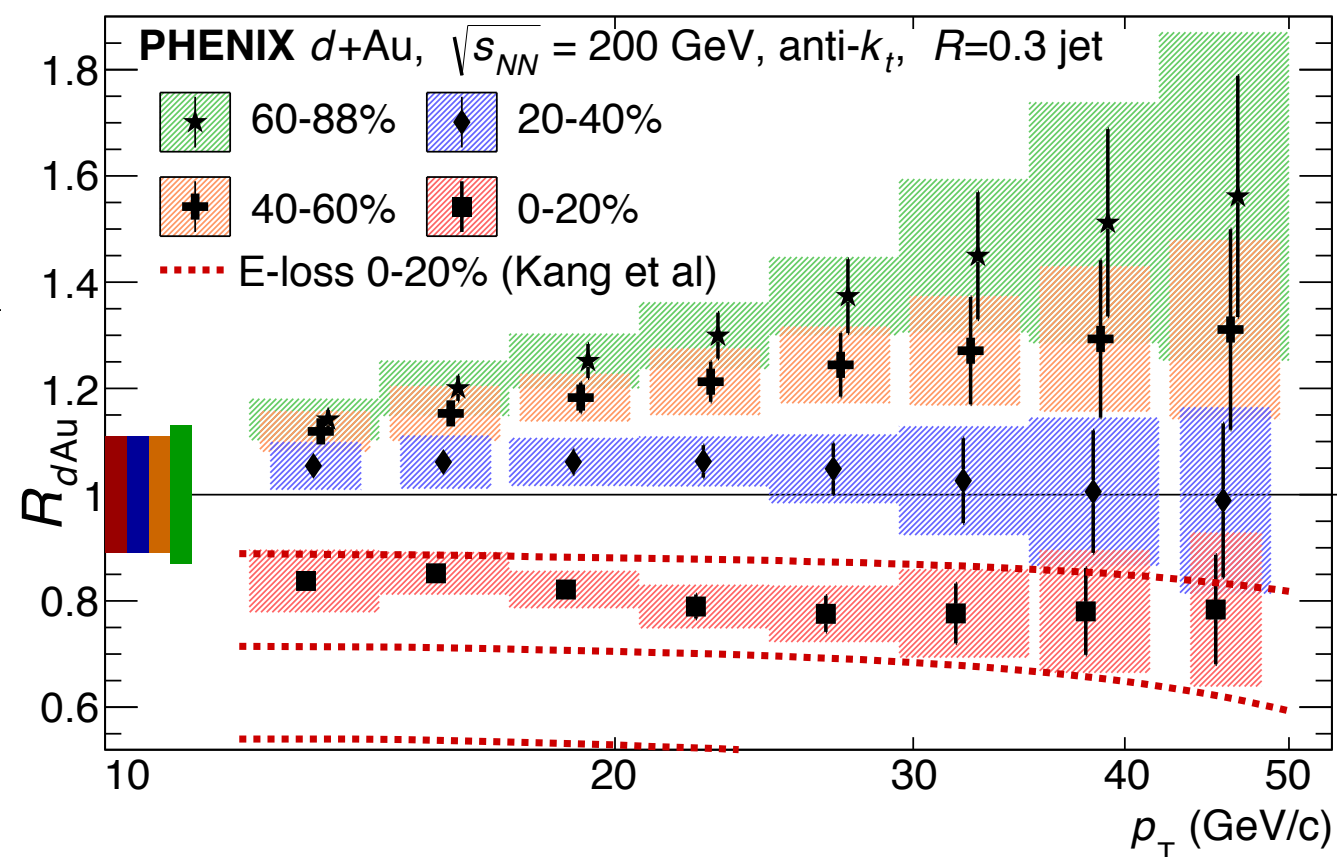
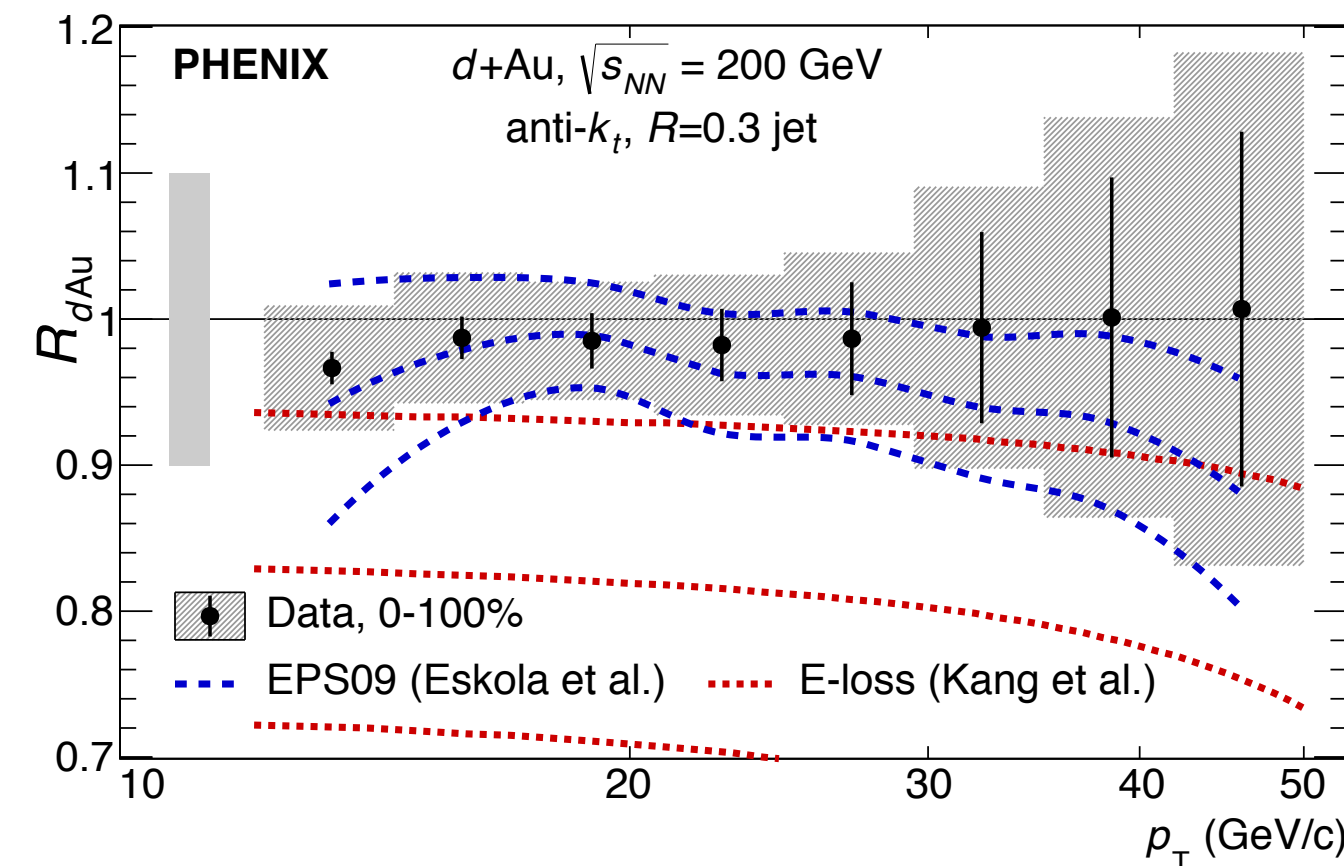
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- 5 IAC spots
- 8 LOC spots (including conveners at conferences)
- 45 invited seminars and talks
- Primary authors or on internal review committees or editors on 59 refereed papers (PHENIX, ATLAS, sPHENIX, few author, review and white papers)





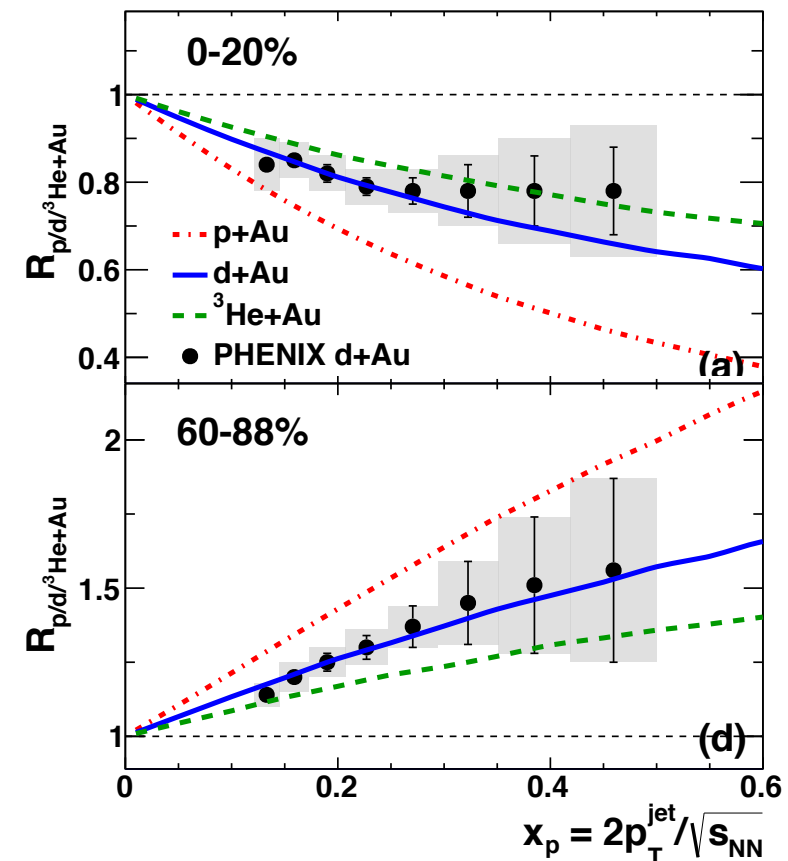
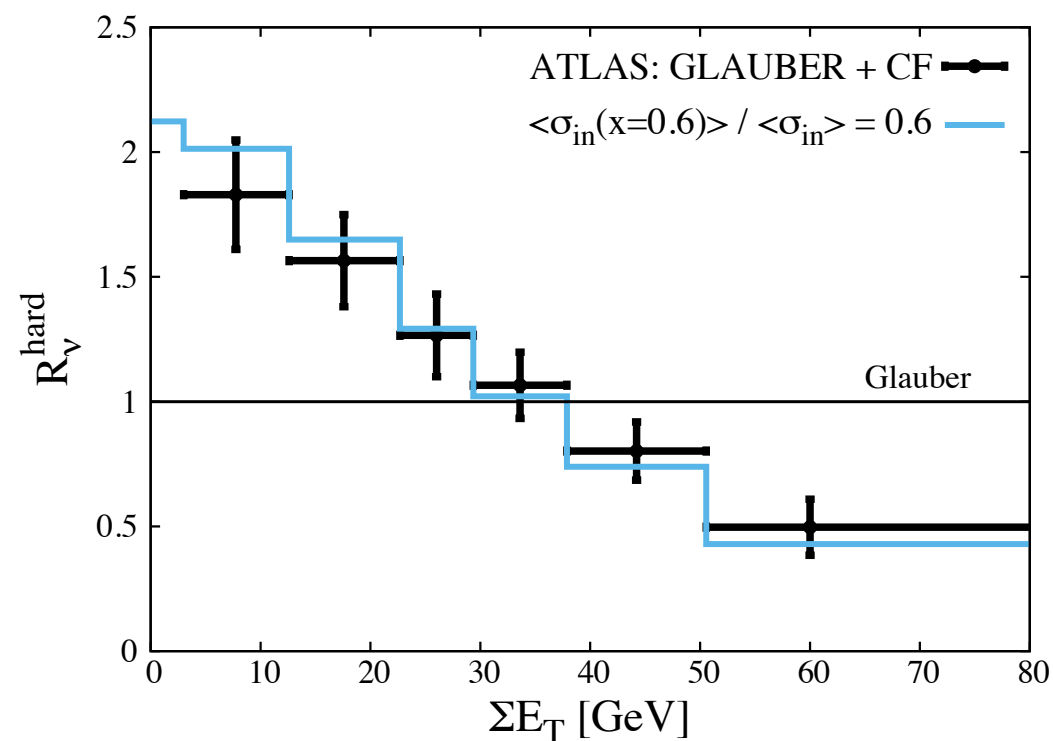
# Jet production in $d+Au$



- PHENIX Collaboration, Centrality-dependent modification of jet-production rates in deuteron-gold collisions at  $\sqrt{s_{NN}} = 200$  GeV, Phys. Rev. Lett. 116 (2016)122301
- Measurement of nPDF / cold-nuclear matter effects over large kinematic range at RHIC
- First measured jet spectrum in non-p+p collision system at RHIC – finalizes QM'12 result; observation of qualitatively similar effects to p+Pb data at LHC



# Possible $x$ -dependent proton size fluctuations



- Alvioli, Cole, Frankfurt, Perepelitsa, Strikman, Evidence for  $x$ -dependent proton color fluctuations in pA collisions at the CERN Large Hadron Collider, Phys. Rev. C93 (2016) 011902
  - ➔ explanation of p+Pb effects at the LHC as arising from “shrinking” or “weakly interacting” proton, with quantitative comparison of model to data
- McGlinchey, Nagle, Perepelitsa, Consequences of high- $x$  proton size fluctuations in small collision systems at RHIC, nucl-th/1603.06607, Accepted by Phys. Rev. C
  - ➔ proposal to test shrinking proton picture with p/d/ $^3\text{He+Au}$  data at RHIC

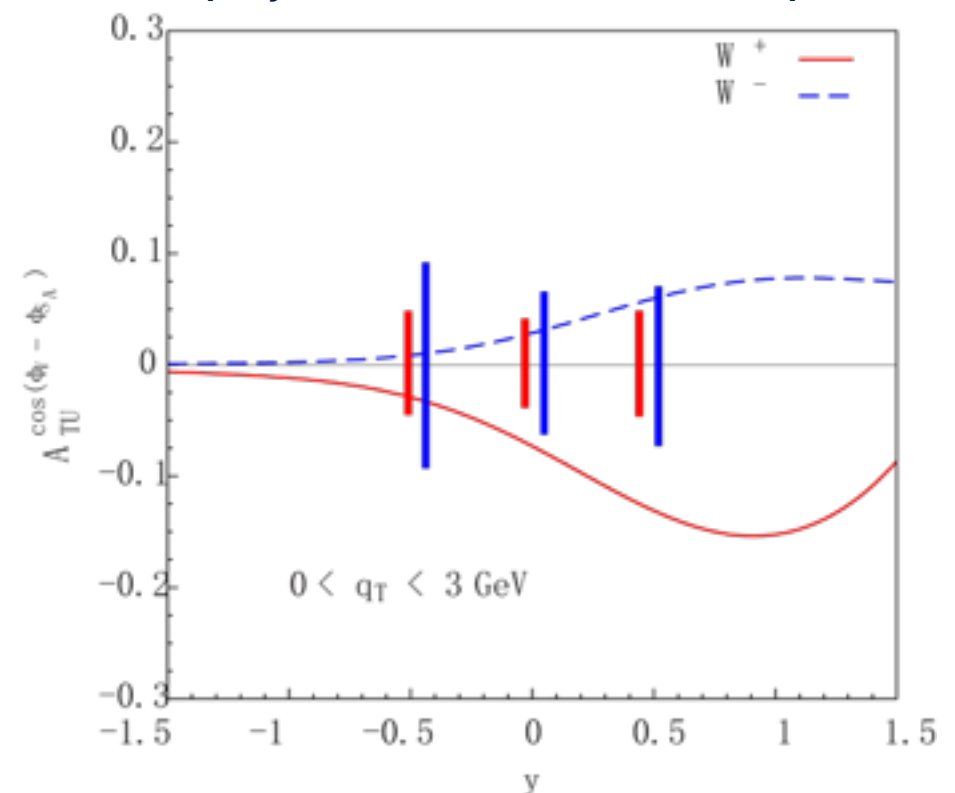


# Huang, Kang, Vitev, Xing, PRD 93 (2016)

Within TMD factorization formalism, presents the cross sections for **weak boson production in polarized pp collisions**. And estimated the spin asymmetries at the top RHIC energy.



- **Curve:** Huang, Kang, Vitev, Xing, PRD 93 (2016)
- **Points:** Jin's naïve expectation of STAR Run17 projection based on Sivers  $A_N$  projection in RHIC Cold QCD plan



$p^\uparrow p \rightarrow W + X \rightarrow (e+\nu)+X$ , transversely polarized p+p collision @  $\sqrt{s} = 510$  GeV

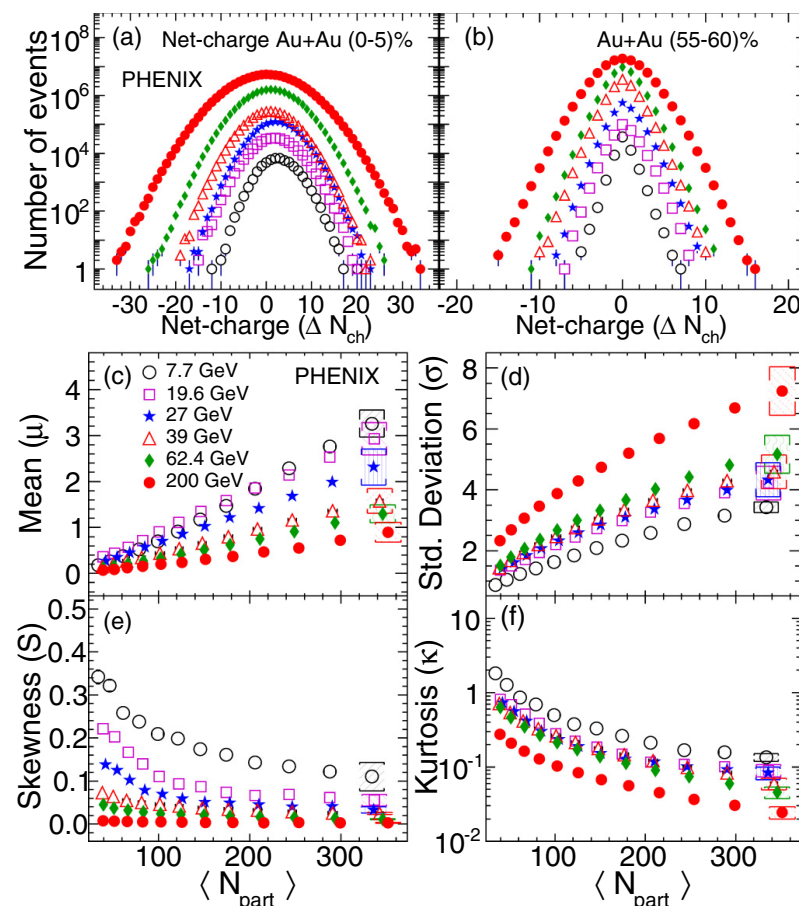
Unique opportunity of probe transversal helicity  $g_{1T}$  via **parity violating single transverse spin asymmetry**. With Sivers measurements, comprehensively tests universality properties of TMDs, constrains the TMD evolution effects

$$g_{1T} = \text{[Diagram 1]} - \text{[Diagram 2]}$$

The diagram shows two circular representations of a quark's spin and transverse momentum. In the first, the spin vector (black arrow) and the transverse momentum vector (red arrow) are both pointing upwards. In the second, the spin vector is pointing upwards and the transverse momentum vector is pointing to the right. The difference between these two states is represented by the minus sign.

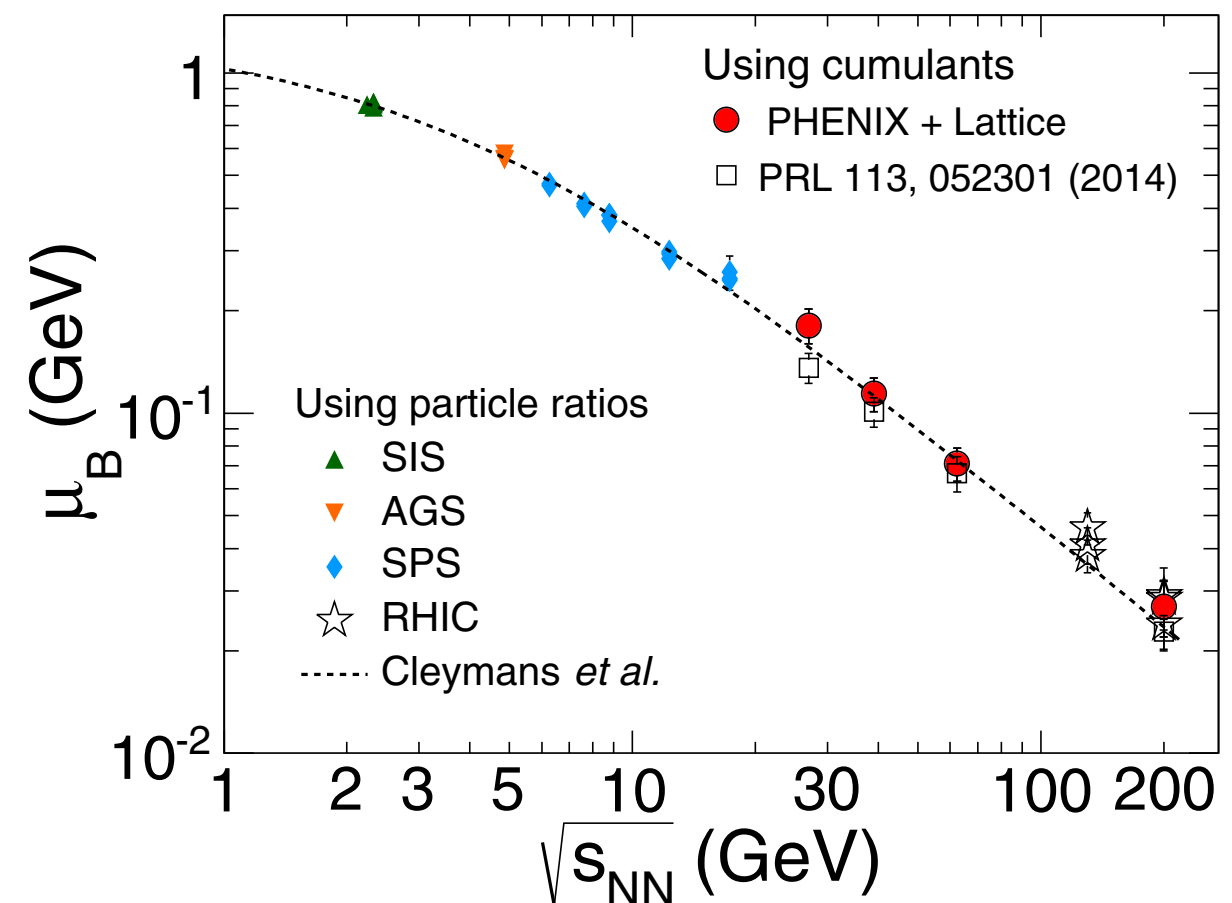
# Net charge fluctuations

“Measurement of higher cumulants of net-charge multiplicity distributions in Au+Au collisions at  $\sqrt{s_{NN}} = 7.7\text{--}200\text{ GeV}$ ”, Phys. Rev. C 93, 011901(R) 2016 (primary authors include **Jeff Mitchell (moved to EBNN)**, Mike Tannenbaum)



uncorrected net charge distributions

products and ratios of cumulants of fully corrected distributions – dependence on volume drops out



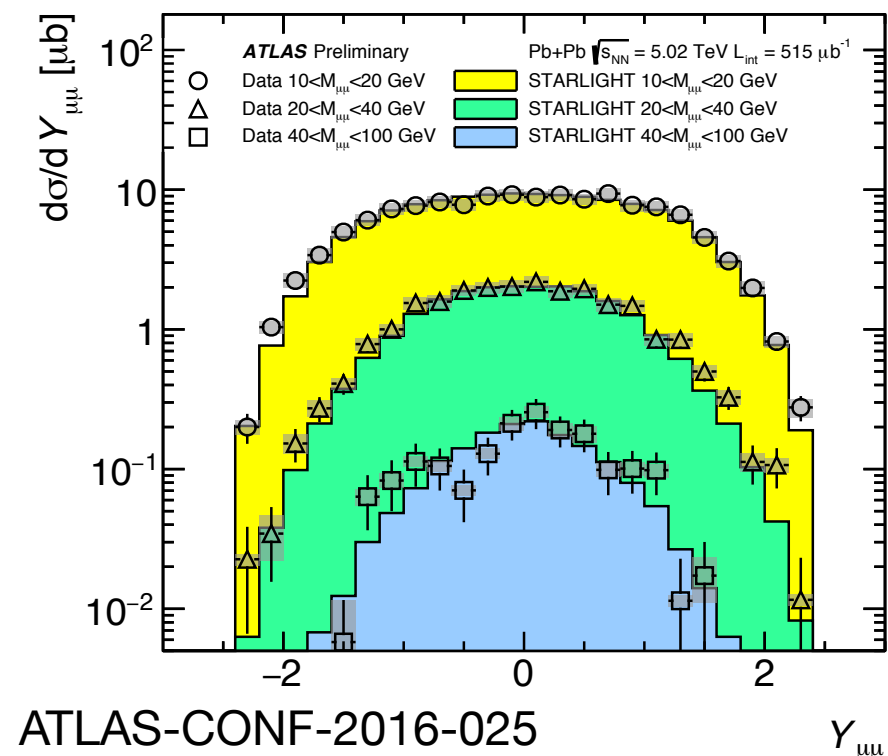
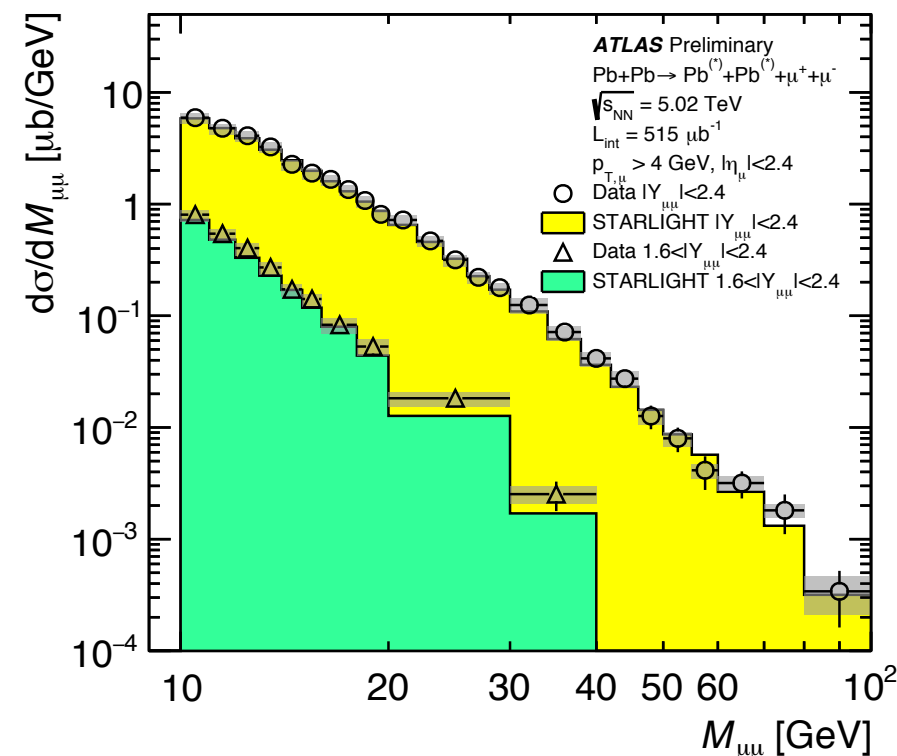
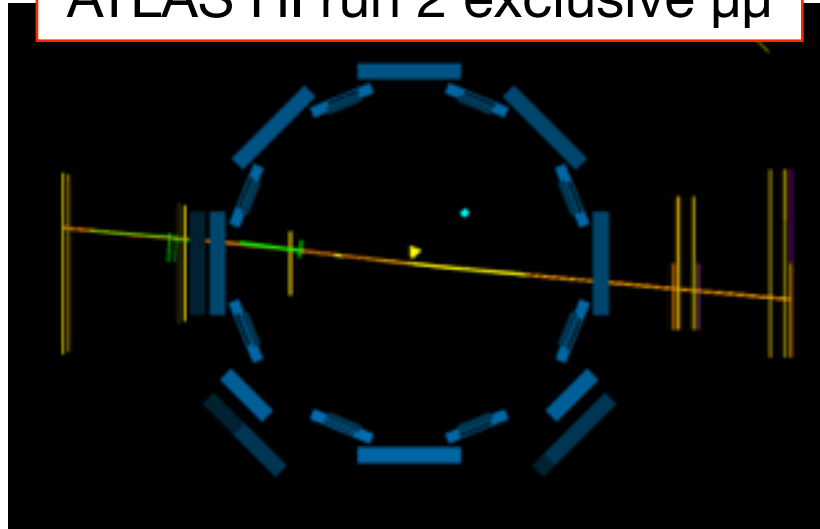
with input from LQCD, determine  $\mu_B$  and  $T_f$  vs  $\sqrt{s_{NN}}$  with small uncertainties

# Ultra-peripheral physics in Pb+Pb with ATLAS

STARLIGHT MC implements collisions of  
Weisacker-Williams quasi-real photons + QED  $\mu^\pm$  production

Strong EM fields, highly contracted:  
source quasi-real photons to  
probe nucleus (& nucleon in  $p$ +Pb).

ATLAS HI run 2 exclusive  $\mu\mu$



ATLAS-CONF-2016-025

<p><b>Photon-pomeron:</b> production of vector mesons (sensitivity to nPDF)</p>	<p><b>Photo-nuclear:</b> jet photoproduction (probe nPDF directly)</p>	<p><b>Photon-photon:</b> dilepton production (&amp; other exclusive states)</p>

# sPHENIX physics

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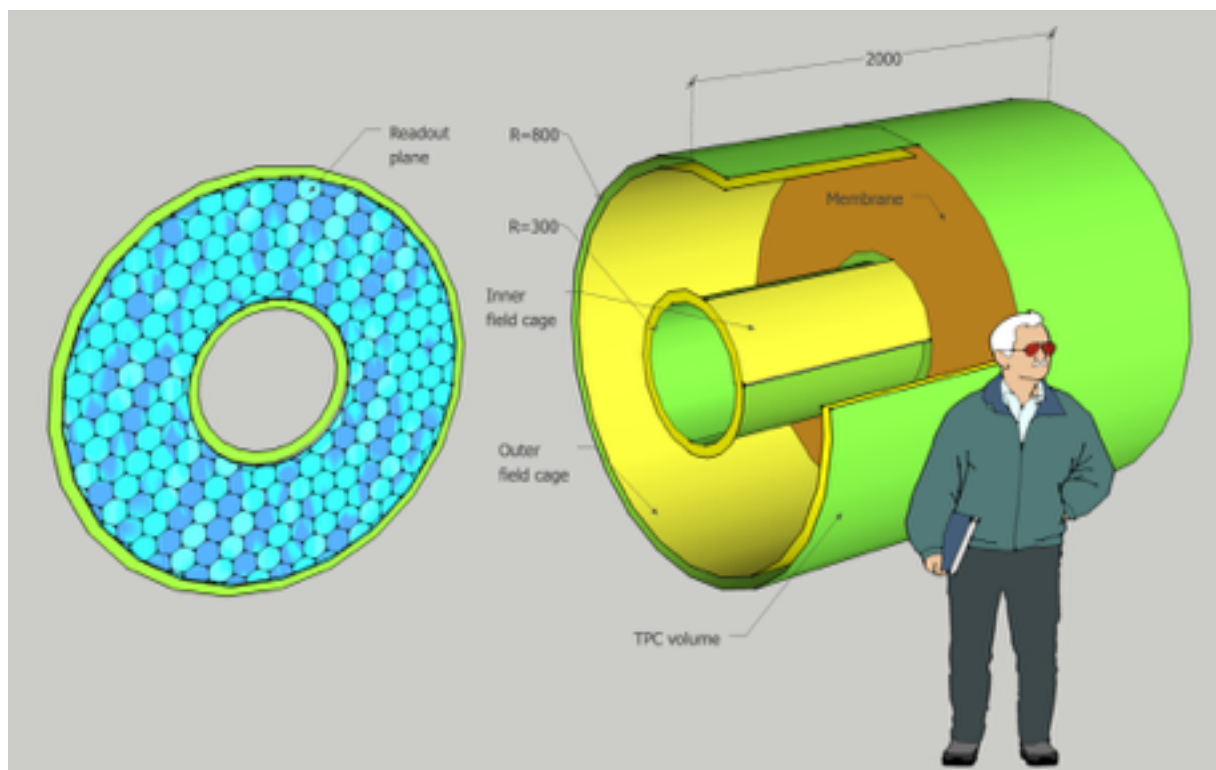
- sPHENIX science case (Morrison, Huang, Perepelitsa)
  - Jet b-tagging studies, now with full GEANT4 detector simulations (Perepelitsa)
  - EMCal simulations – studies of 1D vs 2D projectivity and relevance to Upsilon (Huang)
- Co-conveners of sPHENIX topical groups (Huang, Perepelitsa)
- Computational framework, code development, simulations (Pinkenburg, Purschke, Huang)

# Tracking R&D

sPHENIX requirements Upsilon's with  $\Delta m/m \sim 100 \text{ MeV}/c$ ; DCA  $< 100 \mu\text{m}$ ; pattern recognition in central HI (and in jet cores)

Time projection chamber for sPHENIX tracking

- Fast, compact TPC with GEM readout
- Potentially reusable for eRHIC detector



SBU+Woody, Azmoun, Sakaguchi

Investigation of possible intermediate silicon strip tracker: Hamamatsu sensors being tested



RIKEN+Nouicer



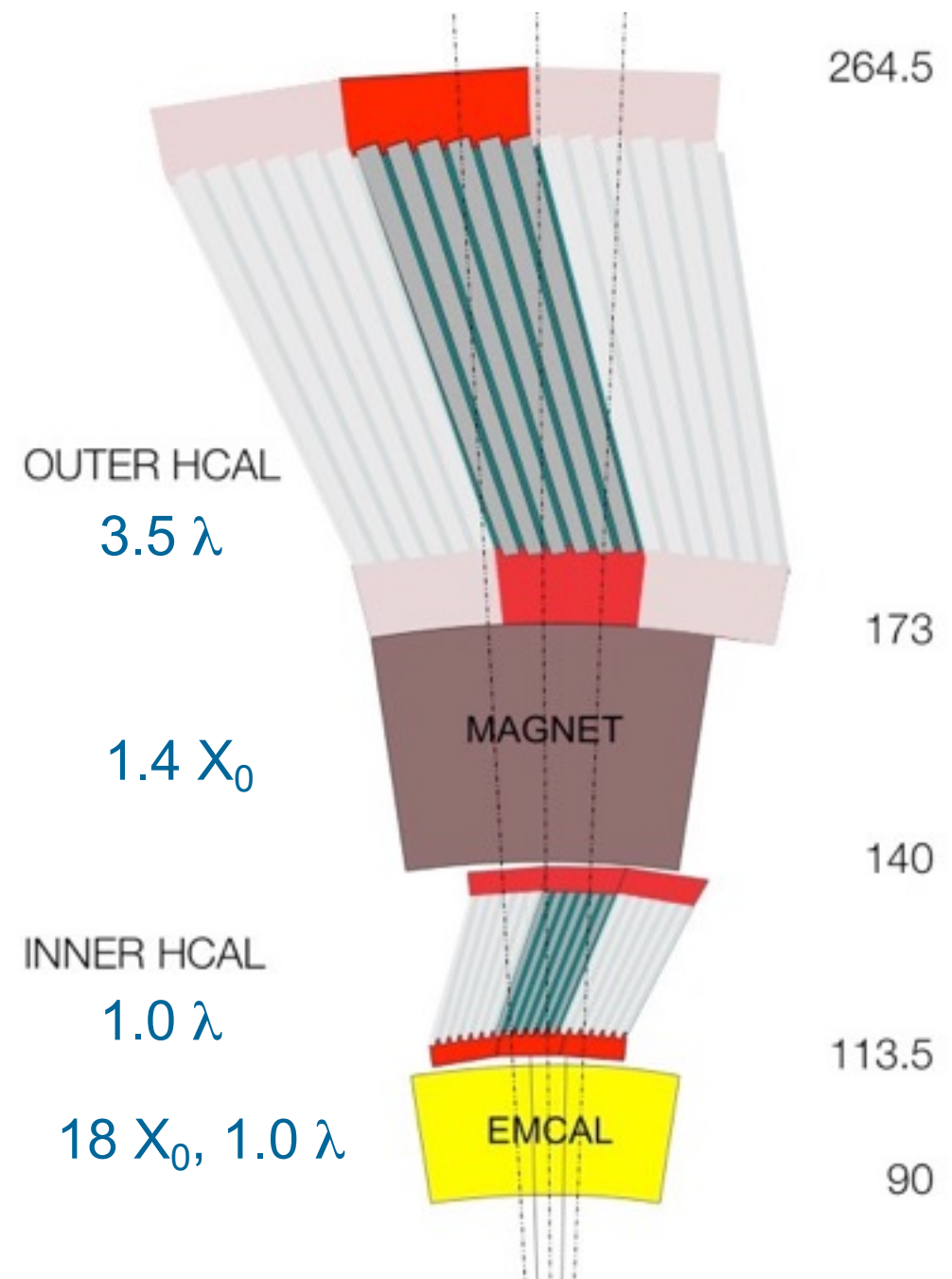
# sPHENIX Calorimeters

azimuthal slice of sPHENIX

HCAL – Steel plates + scintillating tiles  
with WLS fiber readout

EMCAL – Tungsten SciFi SPACAL  
– based on UCLA design, with  
extensions to 2D projectivity and with  
large scale production innovations

Both EMCAL and HCAL read out with SiPMs  
technicians, Kistenev, Haggerty



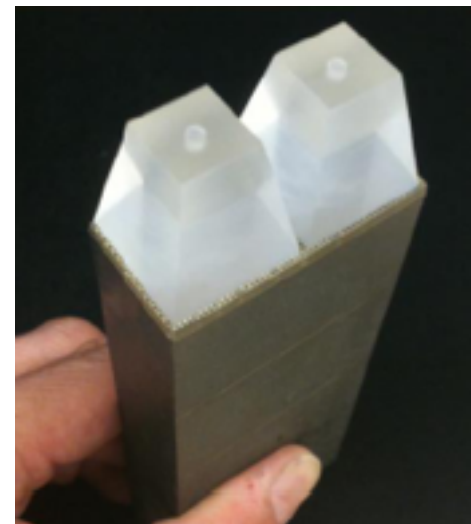
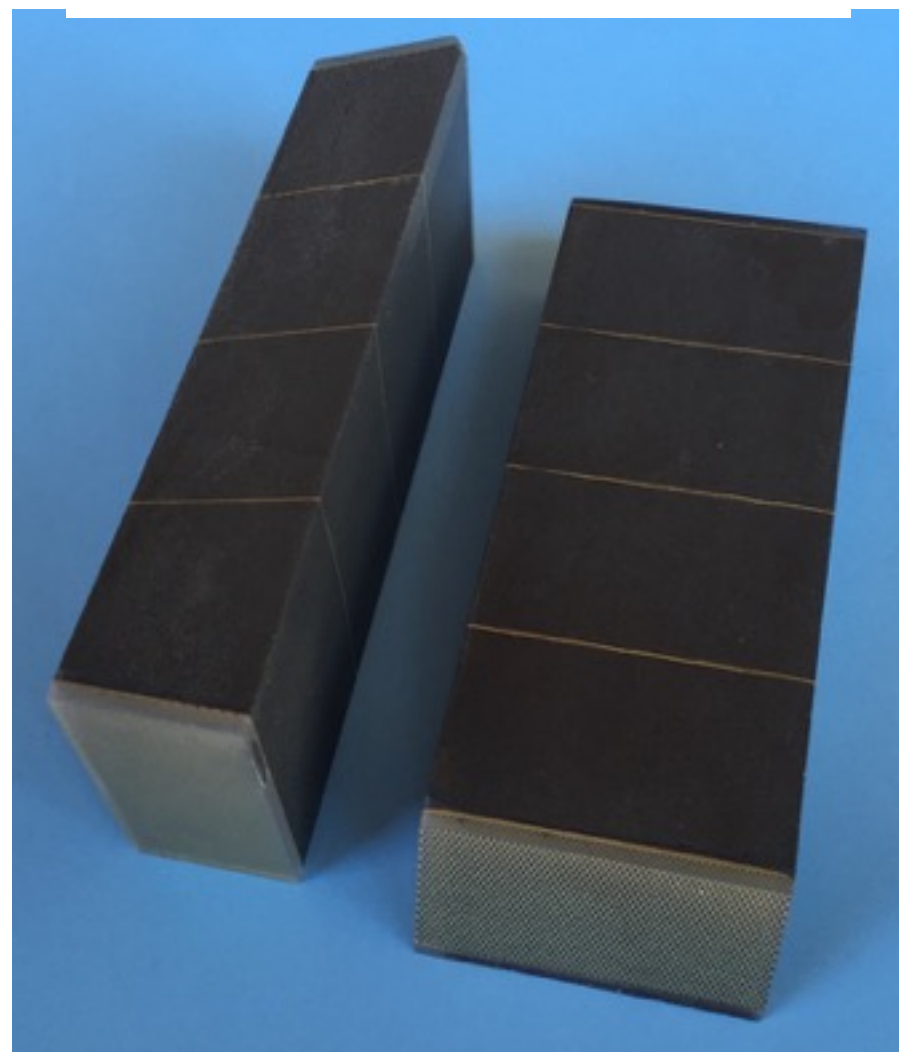
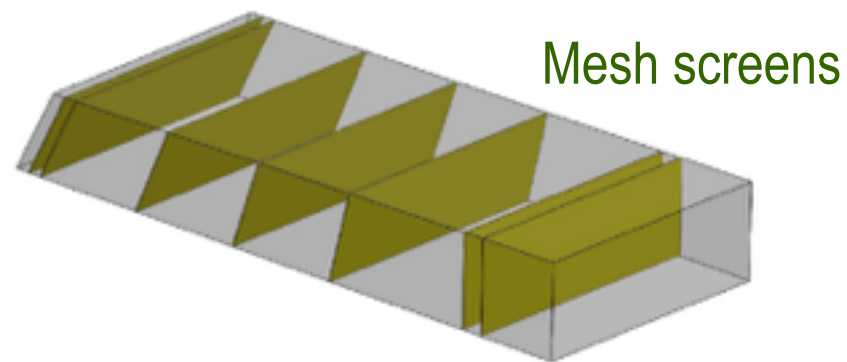
EMCAL + HCAL  $\sim 5.5 \lambda$

# W/SciFi Modules

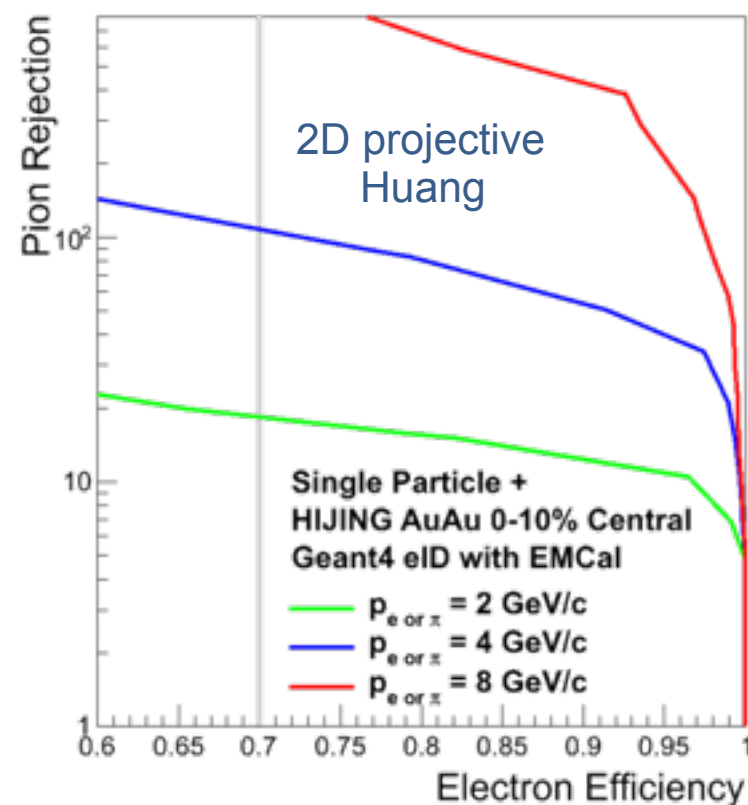
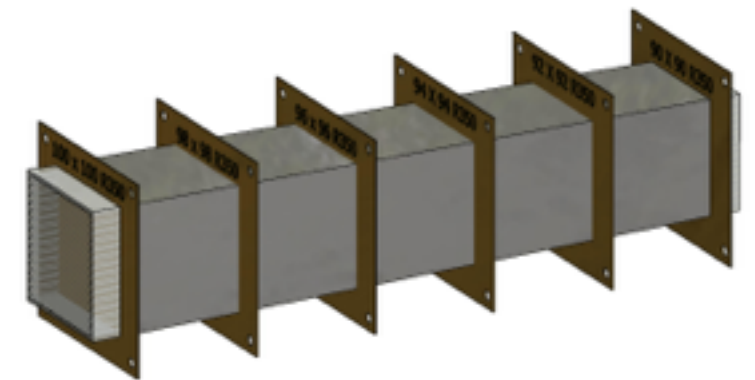
UIUC+Woody, Stoll

## 1D Projective

Light guides and SiPMs are attached to module ends to form towers



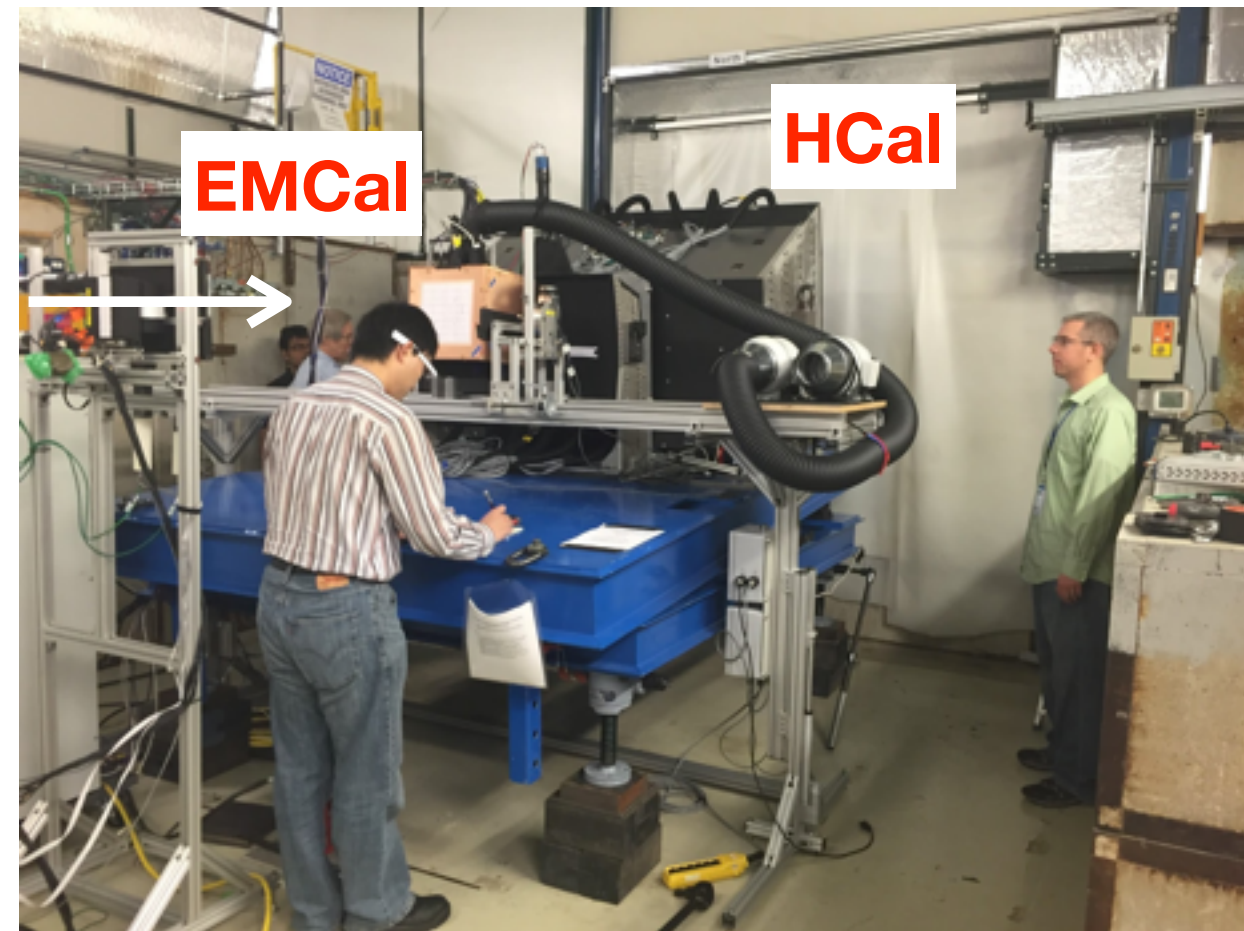
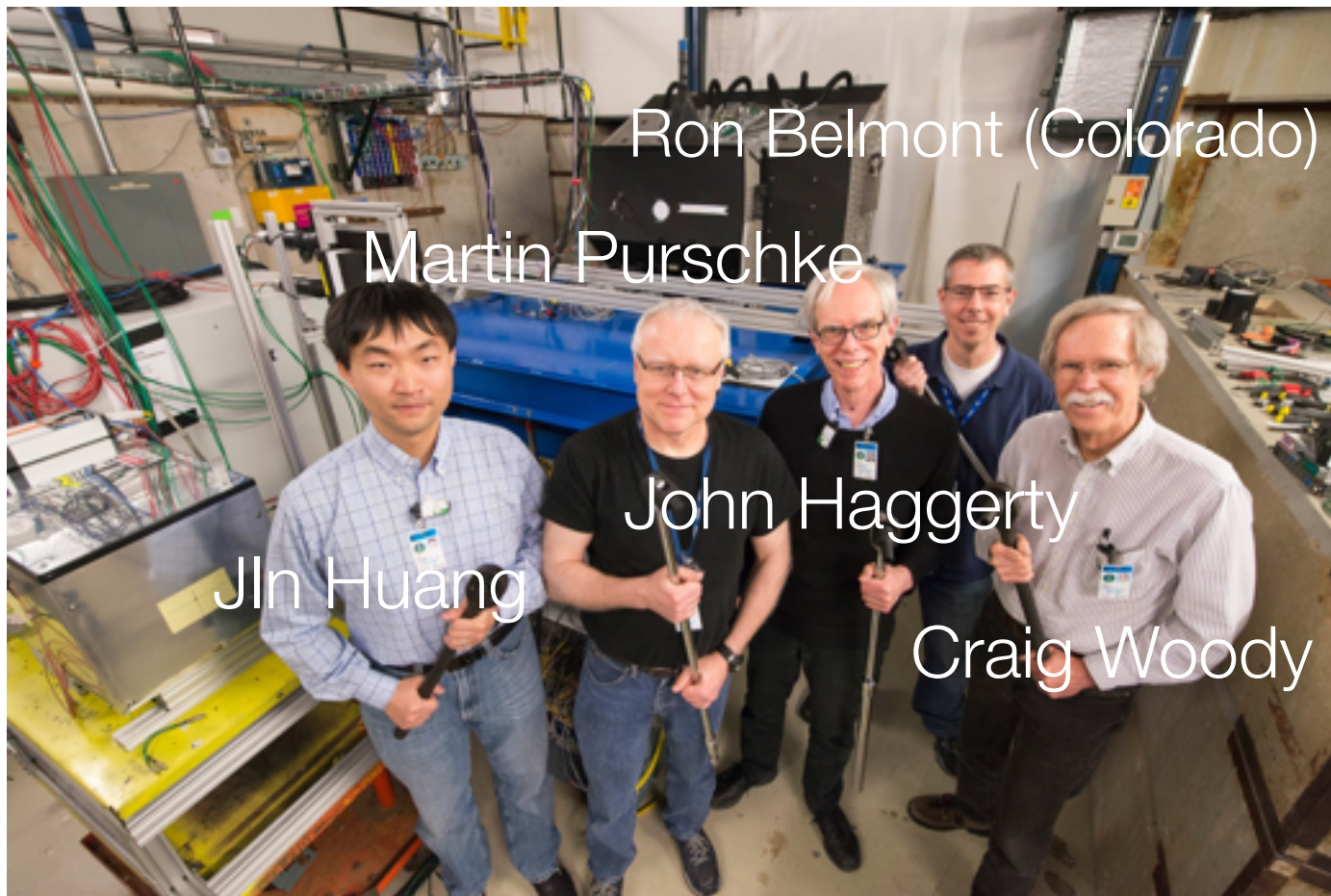
## 2D Projective





# Proving R&D in test beam

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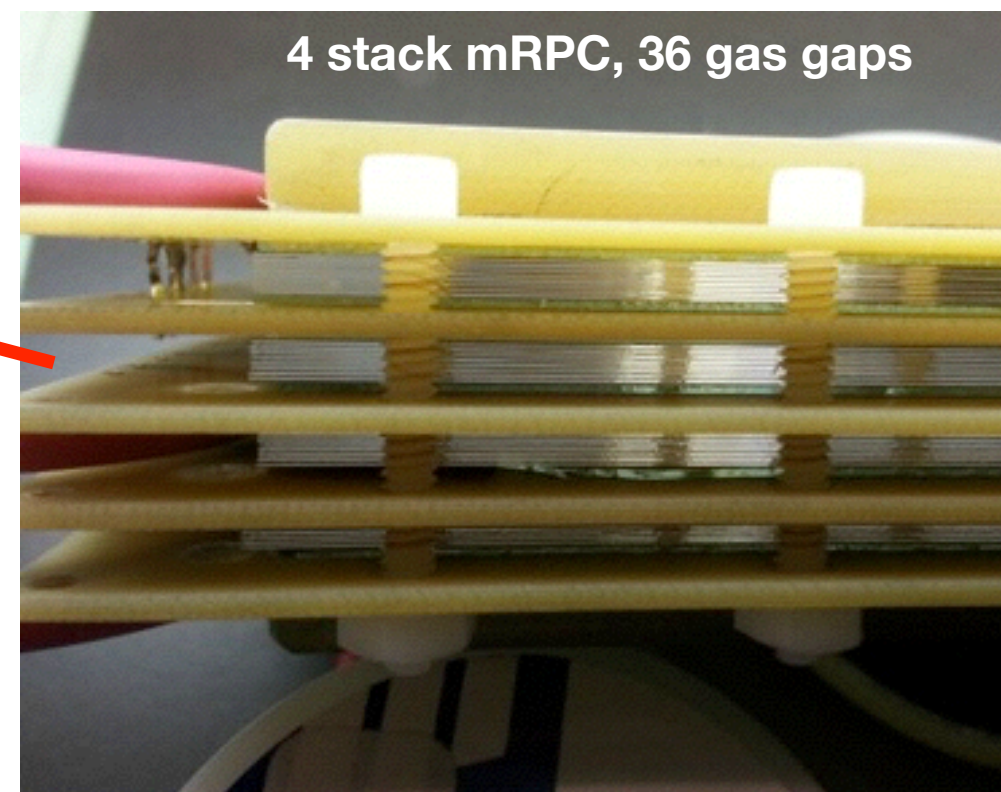
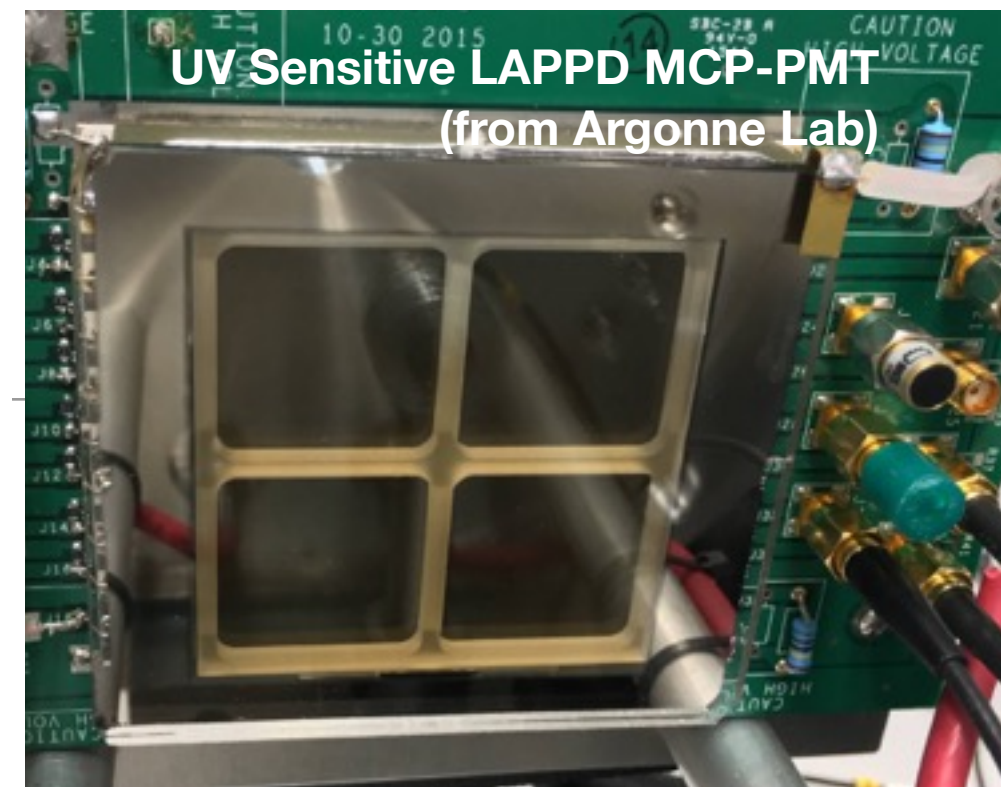
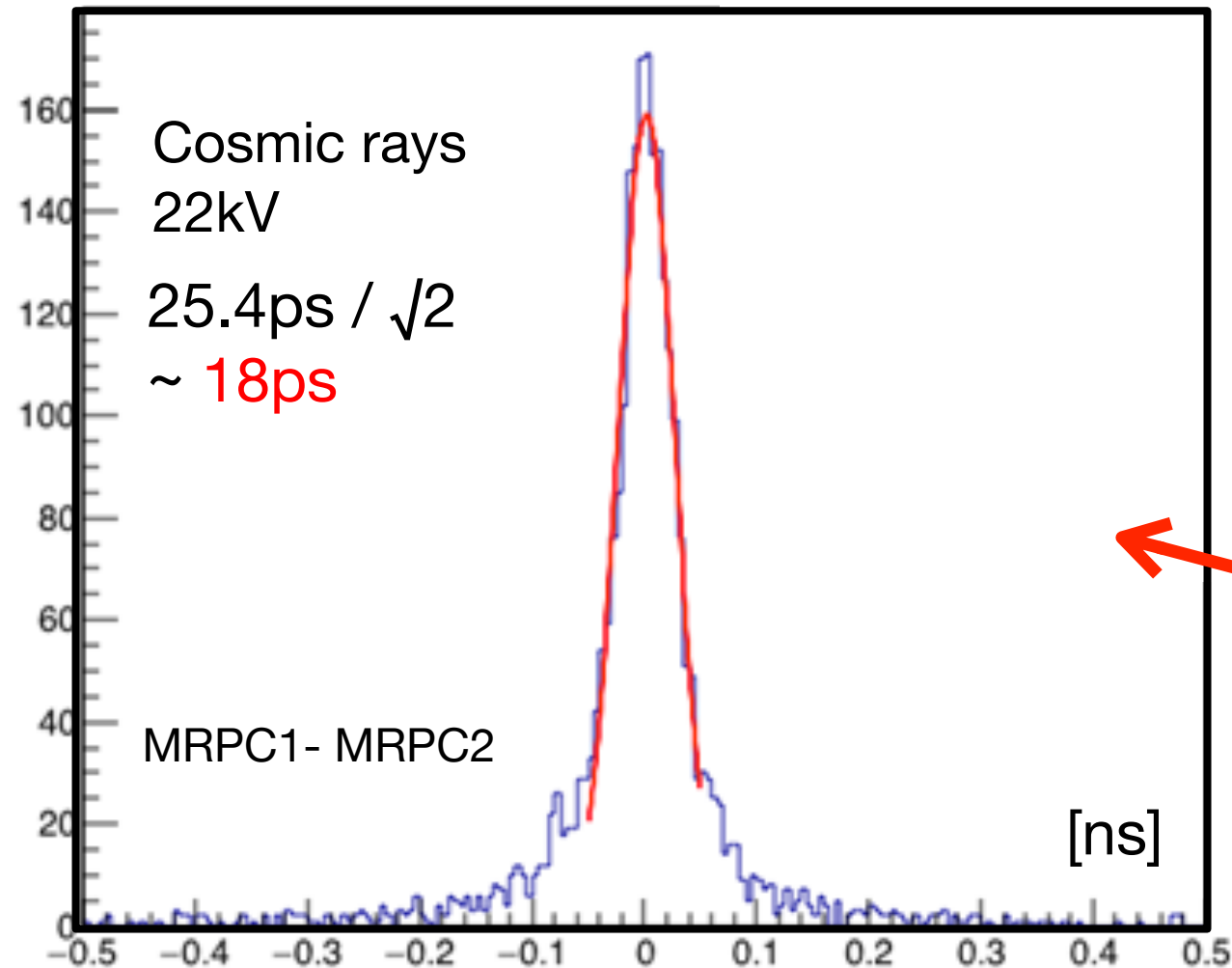


sPHENIX detector development coordinated with the collaboration most notably in beam tests at Fermilab and 2014 and 2016 involving over 30 collaborators from BNL and collaborating institutions



# High Performance TOF R&D

M. Chiu, A. Sukhanov (now at C-AD)



Investigating both mRPC and MCP-PMT technologies

Collaboration with UIUC, Howard, and ACU (M. Perdekamp and M. Chiu are co-PI's)

Funded by M. Chiu PECASE, EIC Generic R&D, and UIUC NSF Grant

Hosts of 4 ACU and 4 Howard undergraduate students in summer 2015 and 2016

Achieved  $\sim 20$  ps with thin glass mRPC

Building sPHENIX compatible DRS4 readout board over next year

# PHENIX outreach

Summer Sunday: Achim Franz  
(moved to Physics Dep't. ESSH)



Set up by BNL/PHENIX technicians



Summer Sunday 2016: 1400 visitors



# Engaging students in research

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- PHENIX operations – shifts, data monitoring, analysis
- Wide array of summer R&D work (EMCal, fast TOF, 3D printing of prototypes)
- Abeliene Christian University (Rusty Towell and students)
- Howard University (Marcus Alfred and students)
- Stony Brook University (Spencer Locks (mech. engineering))



# Summary

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- Group continues to be very successful with key responsibilities and activities: PHENIX operations and collaboration support, PHENIX and ATLAS HI analysis, R&D, planning for future scientific directions
- Scientific staff recently reduced by five FTEs, technical staff reduced by three FTEs; Goldhaber postdoc Perepelitsa now Asst. Prof. at Colorado
- Will rapidly ramp-down PHENIX operations effort (post R&R) – towards 1.5 FTE
- Anticipating sPHENIX, a pivot in direction of group effort – generic R&D, project management, support of test beam, hosting of sPHENIX collaboration. Aim to build and maintain “critical mass” of intellectual strength on key sPHENIX science – obvious target is jet physics
- Exciting, but very challenging period of transition. Maintaining group’s scientific strength, to recruit and retain needed personnel, will require continued support from Laboratory to hire postdocs, junior staff, targeted hires.